Final Image Combine

1. Scale each image in intensity to match the average zeropoint:

$$I_{scaled} = I_{image} \times 10^{-0.4(ZP_{avg} - ZP_{image})}$$

2. Spatially shift the pixels in each image so that M101 is at the center of the image.

3. Create a final image by calculating a the median pixel intensity along a stack of the shifted, scaled images.

This takes 3-5 minutes…..

Applying your photometric solution to the final combined images

Part 1: Instrumental magnitudes

In the notebooks, we defined Instrumental magnitudes in terms of counts/second:

$$m_{inst} = -2.5\log\left(I/t_{exp}\right) + 25$$

So in analyzing the reduced images, we need to define our instrumental magnitudes the same way.

And since we medianed the images (rather than summing them), t_{exp} is the exposure time of an individual image:

- V images: 900 seconds (15 mins)
- B images: 1200 seconds (20 mins)

So turn counts into instrumental magnitudes using those values.

Applying your photometric solution to the final combined images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_{inst,B} - m_B = C_B(B - V) + ZP_B$$

$$m_{inst,V} - m_V = C_V(B - V) + ZP_V$$

FINAL	**B**	**V**
C	0.277	0.233
ZP	3.619	3.541
EXPTIME	1200	900

Applying your photometric solution to the final combined images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_B = m_{inst,B} - C_B(B-V) - ZP_B$$

$$m_V = m_{inst,V} - C_V(B-V) - ZP_V$$

FINAL	**B**	**V**
C	0.277	0.233
ZP	3.619	3.541
EXPTIME	1200	900

Applying your photometric solution to the final combined images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_B = m_{inst,B} - C_B(B - V) - ZP_B$$

$$m_V = m_{inst,V} - C_V(B - V) - ZP_V$$

FINAL	B	V
C	0.277	0.233
ZP	3.619	3.541
EXPTIME	1200	900

But wait…

Subtract one from the other:

$$m_B - m_V = \left[m_{inst,B} - m_{inst,V}\right] - [C_B - C_V](B - V) - [ZP_B - ZP_V]$$

$$B - V = \left[m_{inst,B} - m_{inst,V}\right] - [C_B - C_V](B - V) - [ZP_B - ZP_V]$$

$$(B - V)(1 + [C_B - C_V]) = \left[m_{inst,B} - m_{inst,V}\right] - [ZP_B - ZP_V]$$

$$(B - V) = \left(\left[m_{inst,B} - m_{inst,V}\right] - [ZP_B - ZP_V]\right) / \left((1 + [C_B - C_V])\right)$$

Applying your photometric solution to the final combined images

Summary

First measure counts and calculate instrumental magnitudes in each filter:

$$m_{inst,B} = -2.5\log\left(I_B/t_{exp,B}\right) + 25$$
$$m_{inst,V} = -2.5\log\left(I_V/t_{exp,V}\right) + 25$$

Then calculate the color:

$$(B-V) = \left(\left[m_{inst,B} - m_{inst,V}\right] - [ZP_B - ZP_V]\right)/\left((1 + [C_B - C_V])\right)$$

Then insert that color into the photometric solution to calculate magnitudes:

$$m_B = m_{inst,B} \ - C_B(B-V) - ZP_B$$

$$m_V = m_{inst,V} \ - C_V(B-V) - ZP_V$$

FINAL	B	V
C	0.277	0.233
ZP	3.619	3.541
EXPTIME	1200	900

One last step – correcting for galactic extinction

After all photometry is done and you have your "final" magnitudes and colors, you want to correct for galactic extinction. Dust in the Milky Way (which we are looking through) both dims and reddens the light from M101.

Look up the galactic extinction on NED, using the estimate from Schlafly and Finkbeiner (2011). Then correct for extinction in each band by doing:

$$m_{B,0} = m_{B,obs} - A_B$$
$$m_{V,0} = m_{V,obs} - A_V$$

And then correct the color by doing either

$$(B - V)_0 = (B - V)_{obs} - (A_B - A_V)$$

or

$$(B - V)_0 = m_{B,0} - m_{V,0}$$

But not both! That is, don't calculate your color from the corrected magnitude and then *also* apply the reddening correction.

Applying your photometric solution to the final combined images

Summary

First measure counts and calculate instrumental magnitudes in each filter:

$$m_{inst,B} = -2.5\log\left(I_B/t_{exp,B}\right) + 25$$
$$m_{inst,V} = -2.5\log\left(I_V/t_{exp,V}\right) + 25$$

Then calculate the color:

$$(B - V) = \left(\left[m_{inst,B} - m_{inst,V}\right] - [ZP_B - ZP_V]\right)/\left((1 + [C_B - C_V])\right)$$

Then insert that color into the photometric solution to calculate magnitudes:

$$m_B = m_{inst,B} \; - C_B(B - V) - ZP_B$$

$$m_V = m_{inst,V} \; - C_V(B - V) - ZP_V$$

Fill in this table using the info from the image headers ⇒

FINAL	**B**	**V**
C		
ZP		
EXPTIME	1200	900

Working with your final combined images

In a terminal window:

- `cd ~/M101`
- `mv Bdata/stack_med.fits M101B.fits`
- `mv Vdata/stack_med.fits M101V.fits`
- `ds9 M101B.fits M101V.fits &`

In ds9:

- Frame → Single Frame
- Frame → Lock → Frame → WCS
- Scale → Scale Parameters → -10 to 3,000
- Scale → Log
- Frame → Lock → Scale
- Frame → Lock → Colorbar

This sets up ds9 so you can zoom, pan, and change the display stretch on one image, then hit "tab" and see the other image similarly displayed.

ds9 regions (Regions → Shape):

- Ruler: will measure distances on image in different units
- Circles: for photometry
  - Make region around object, measure total flux in object
  - Move region to nearby blank sky, measure total flux in blank sky
  - Subtract blank sky flux from object flux to get total flux
  - You can also enter a (α, δ) or (X, Y) coordinate for the region center and it will move to that position.